# Phylogenetic position, morphology and natural history of the Vietnamese water skink *Tropidophorus noggei* Ziegler, Vu & Bui, 2005 (Sauria: Scincidae)

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**Phylogenetic position, morphology and natural history of the Vietnamese water skink *Tropidophorus noggei* Ziegler, Vu & Bui, 2005 (Sauria: Scincidae).** - The depressed-bodied water skink species *Tropidophorus noggei* was recently described from Phong Nha - Ke Bang National Park, a karst forest region in the Truong Son, central Vietnam. Subsequent field research at the type locality led to the finding of additional specimens which allowed to extend the knowledge about the species' morphology including hemipenis morphology. The molecular positioning of the species within *Tropidophorus* supports that the body depression recognized in several Indochinese taxa is likely to have occurred at least twice in parallel as an adaptation to saxicolous habitats. New insights into the natural history of *Tropidophorus noggei* are given, including habitat choice, abundance, activity and habits, as well as the species' feeding and reproductive ecology.

**Keywords:** Sauria - Scincidae - Lygosominae - *Tropidophorus* - *T. noggei* - mitochondrial DNA sequence data - systematics - morphology - natural history - Vietnam.

## INTRODUCTION

Recently, Honda *et al.* (2005) presented a molecular phylogeny of the oriental lygosomine genus *Tropidophorus* Duméril & Bibron, 1839, including the recently described *T. latiscutatus*, *T. matsuii* and *T. murphyi* (Hikida *et al.*, 2002). These water skink species exclusively share distinctly depressed bodies, as well as saxicolous habitats. Hikida *et al.* (2005) assumed that the strongly depressed body shape reflects an adaptation to narrow rock crevices as shelters, as known also from few other lizard families, such as Cordylidae Gekkonidae, Iguanidae, Lacertidae, and Xenosauridae

(Vitt, 1981; Doughty & Shine, 1995; Ballinger *et al.,* 2000). Subsequently, the analyses of Honda *et al.* (2005) showed that the characteristic body shape has independently evolved in *T. murphyi* and in the common ancestor of *T. latiscutatus* and *T. matsuii.* However, another depressed-bodied *Tropidophorus* species was not included in Honda *et al.*'s (2005) molecular approach: *T noggei*, which was described recently from a karst forest region in the Truong Son mountain range, Vietnam (Ziegler *et al.,* 2005). It is the aim of this study to clarify the phylogenetic position of this further depressed-bodied *Tropidophorus* by molecular means as well as to add new data to the morphology and natural history of the barely known species.

## MATERIAL AND METHODS

Specimens collected by local people subsequently to the original description of *T. noggei* (Ziegler *et al.,* 2005) in the region of Phong Nha - Ke Bang, Quang Binh Province, Vietnam, were deposited in the following collections: Department of Herpetology and Ichthyology, Muséum d'histoire naturelle, Geneva (MHNG), Switzerland (MHNG 2683.99); Science Research Centre of the Phong Nha - Ke Bang National Park, Quang Binh Province, Vietnam (PNNP 111, PNNP 112, PNNP 174, PNNP 175).

To examine the phylogenetic position of *Tropidophorus noggei* in the general framework of related species of the genus we sequenced a portion of the mitochondrial 16S rRNA gene of MHNG 2693.99 (GenBank accession number: EF611186) and compared it with the following species of *Tropidophorus* (sequences were taken from the GenBank): *T. berdmorei* (AB028823), *T. grayi* (AB222957), *T. partelloi* (AB222962), *T. baconi* (AB222953), *T. sinicus* (AB222954), *T. cocincinensis* (AY308323 and AB222959), *T. baviensis* (AB222958), *T. hainanus* (AB222960), *T. murphyi* (AB222961), *T. robinsoni* (AB222955), *T. thai* (AB222956), *T. latiscutatus* (AB222950), *T. matsuii* (AB222952). *T. brookei* (AB222949), *T. beccarii* (AB222951), and *Tropidophorus* sp. (AY308322). *Eutropis longicaudata* (AF153572) was used as outgroup.

DNA was extracted using a modified Chelex-Protocol (Walsh *et al.,* 1991; Schmitz, 2003). The primers 16sar-L (light chain; 5' - CGC CTG TTT ATC AAA AAC AT - 3') and 16sbr-H (heavy chain; 5' - CCG GTC TGA ACT CAG ATC ACG T - 3') of Palumbi *et al.* (1991) were used to amplify a section of the mitochondrial 16S ribosomal RNA gene. PCR cycling procedure followed Schmitz *et al.* (2005). PCR products were purified using Qiaquick purification kits (Qiagen). Sequences (including complimentary strands for assuring the accuracy of the sequences) were obtained using an automatic sequencer (ABI 377). The obtained sequences (lengths referring to the aligned sequences including gaps) comprised 593 bp. Sequences were aligned using ClustalX (Thompson *et al.,* 1997; default parameters) and manually checked using the original chromatograph data in the program BioEdit (Hall, 1999). We used PAUP* 4.0b10 (Swofford, 2002) to compute the uncorrected pairwise distances for all sequences.

We performed maximum parsimony (MP), Neighbor-joining (NJ) and Bayesian (PP) reconstructions. For Bayesian analysis parameters of the model were estimated

from the data set using MrModeltest 2.2 (Nylander, 2005). The NJ-analysis used the uncorrected 'p-distances'. Additionally, we used bootstrap analyses with 2000 (MP) and 20000 (NJ) pseudoreplicates to evaluate the relative branch support in phylogenetic analysis. For the MP analysis, we used the "heuristic search" with the "random addition" option of PAUP* (Swofford, 2002) with 10 replicates, using the TBR (tree bisection-reconnection) branch swapping option. All Bayesian analyses were performed with MrBayes, version 3.0b4 (Huelsenbeck & Ronquist, 2001). We ran two MCMC analyses for $10^6$ generations each. The initial 100000 (10%) trees were disregarded as "burn-in". We consider posterior probabilities (PP) of 95% or greater to be significantly supported. The exact parameters used for the Bayesian analyses followed those described in detail by Reeder (2003).

Specimens recorded during ecological studies in Phong Nha - Ke Bang from 17 June to 27 August 2006 by two of us (AH and TZ) were only studied in the field or captured for taking most important measurements (to the nearest milimeter, using a digital vernier caliper) and scalation characters and were subsequently released. Capture took place at night, beyond the skink's activity phase. We used a long pair of tweezers to reach and grasp the skinks in their hiding places within narrow karst rock crevices. Prior to their release, specimens were marked by a green-coloured deco marker (label Edding 4000) for enabling the recognition of eventual recaptures.

Abbreviations are as follows: SVL - snout-vent length; TaL - tail length; TL - total length; HL - head length (distance from tip of snout to posterior margin of interparietal); HW - maximum head width; BB - dorsal body bands between limbs; MS - transversal midbody scale count; MD - middorsal (paravertebral) scales (from the posterior end of parietals to posterior margin of thigh); D - transversal dorsal scales at midbody; V - transversal ventral scales at midbody; L - keeled rows of lateral scales at midbody.

The invertedly fixed hemipenes of the adult male specimen MHNG 2683.99 were removed from the tail base and brought to subsequent eversion based on a method described by Pesantes (1994) for snakes and then successfully applied to lizards by Ziegler & Böhme (1997). After the temporarily storation in 2% potassium hydroxide solution (KOH) at 25°C, the subsequently everted outer genital organs were stored in 70% ethanol (see also Ziegler *et al.,* 2005).

For measuring the temperature and humidity we used a digital thermo- and hygrometer; weighing of the skinks (in cotton bags) was carried out with a spring balance (maximum 100g, in 1g steps). Skink photographs in the field were taken with a Canon IXUS 55 digital camera.

## RESULTS AND DISCUSSION

### MOLECULAR SYSTEMATICS

All molecular analyses produced an almost identical tree topology shown in Fig. 1. We excluded 106 bp from all analyses which were too variable to be aligned unambiguously. The heuristic search of the MP analysis produced 4 most-parsimonious trees (tree length = 261; CI = 0.475; RI = 0.557; RC = 0.264). The comparison between the different likelihood scores for each model showed that the GTR+I+G model (Yang
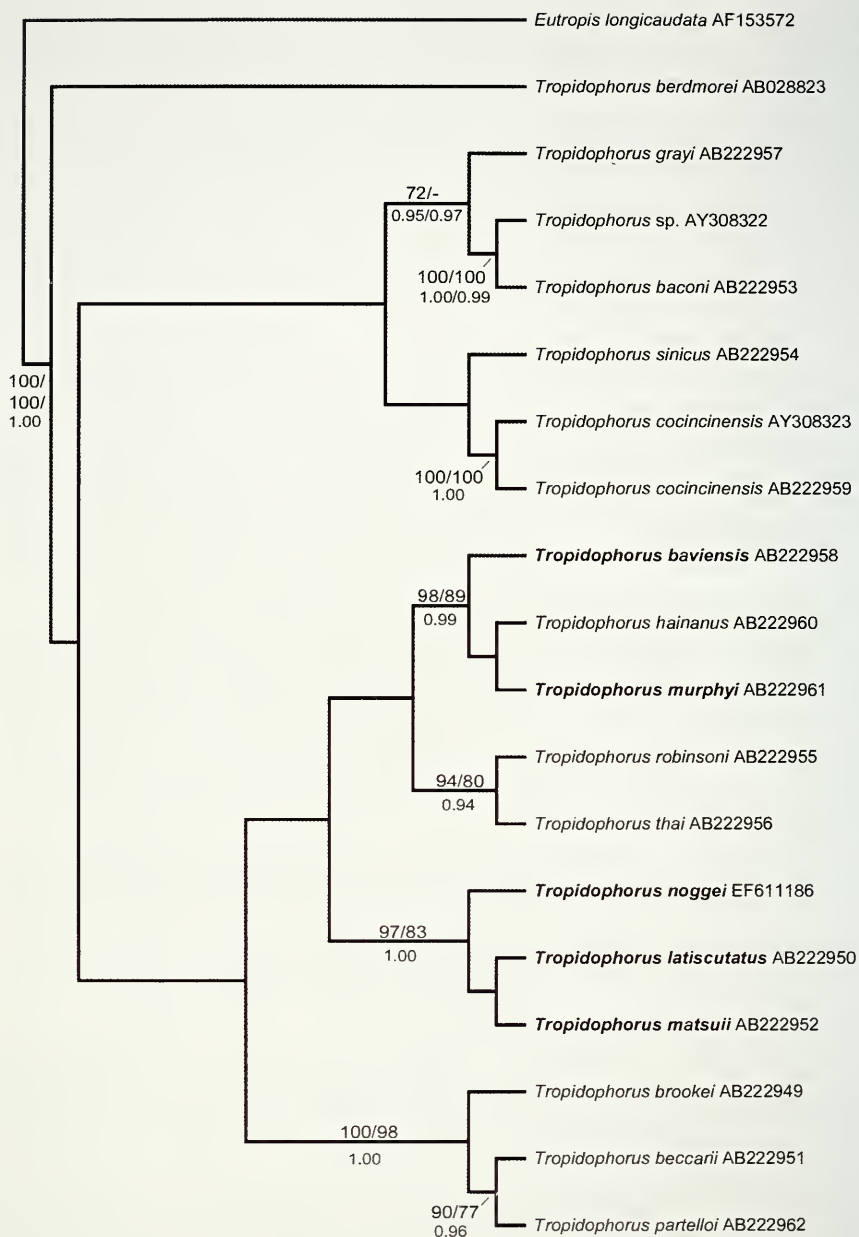
FIG. 1

Cladogram based on 487 bp of the mitochondrial 16S ribosomal RNA gene sequences. Values above the nodes represent bootstrap values in percent for neighbor-joining (NJ) and maximum parsimony (MP) analyses, respectively; lower values are Bayesian posterior probabilities (PP). Only significant values (≥70 for NJ and MP; ≥0.95 for PP) are shown. Depressed-bodied species of *Tropidophorus* are written in bold.

*et al.*, 1994) was determined to be the optimal ML model for data set. This model incorporates unequal base frequencies [$\pi_{(A)} = 0.3274$, $\pi_{(T)} = 0.2145$, $\pi_{(C)} = 0.2593$, $\pi_{(G)} = 0.1987$], a proportion of invariable sites (I = 0.4742), and a gamma distribution shape parameter (a = 0.4343). The optimal ML tree had a log-likelihood of -lnL = 2183.2847.

As expected for the comparatively short sequences compared, none of the trees showed any basal resolution but all analyses identified the same 7 terminal groups, all of which received significant bootstrap values to strongly support them. Therefore, we cannot specifically comment on the valitidy of the results of Honda *et al.* (2005) which indicated a basal split within *Tropidophorus* and separated a clade of continental Indochinese species exclusive of *T. cocincinensis* and *T. microlepis* from one comprising *T. cocincinensis*, *T. microlepis* and species from Borneo, Sulawesi and the Philippines. But in all our analyses *Tropidophorus noggei* clustered well supported by bootstrap values (NJ: 94/MP: 83/PP: 1.00) in a clade with *T. latiscutatus* and *T. matsuii* and therefore fits well into the principal "Indochina clade" of Honda *et al.* (2005).

Within *Tropidophorus* four more or less depressed-bodied species had been known before the description of *T. noggei* (Hikida *et al.*, 2002; Honda *et al.*, 2005; Ziegler *et al.*, 2005). While two moderately depressed species were collected from small areas in northeastern and eastern Thailand (*T. latiscutatus*, *T. matsuii*), one futher species with an extremely depressed head and body was found from one limited area in northern Vietnam (*T. murphyi*). All three species most resemble *T. baviensis* Bourret, 1939 from northern Vietnam in body size, body shape, and scutellation. However, the body depression in *T. baviensis* is by far not so prominent as in the other three species. In all our phylogenetic trees *T. baviensis* clusters with very significant bootstrap support in one of the terminal clades together with *T. hainanus* and *T. murphyi* (NJ: 98/MP: 89/PP: 0.99). The newly described *Tropidophorus noggei* is a further species with a moderately depressed body and head, and its phylogenetic position as a member of a clade together with *T. latiscutatus* and *T. matsuii* (which are clearly separated from the former clade) confirms that the body depression recognized in several Indochinese species is likely to have occurred convergently at least twice as an adaptation to saxicolous habitats, as was presumed by Honda *et al.* (2005). Also the direct comparison of the uncorrected distance data confirms both the species status of *T. noggei* from its closest relatives *T. matsuii* and *T. latiscutatus* (3.29% and 2.68%, respectively), as well as the distinctness and separation of the two above metioned terminal clades (internal distances: 2.68%-3.29% ("*noggei*-clade") and 2.88%-3.91% ("*baviensis*-clade"); distances between the two clades: 5.76%-6.78%).

MORPHOLOGY

Beside the male holotype ZFMK 83668, the specimen MHNG 2683.99 represents the second collected male specimen of *Tropidophorus noggei*. Hence, we herein provide a detailed description in the following:

The measurements of MHNG 2683.99 are as follows: snout-vent length 101.8 mm; tail length 104.5 mm; total length 206.3 mm; head length (distance from tip of snout to posterior margin of interparietal) 17.1 mm; head width 16.7 mm; head height 10.3 mm; snout length (from tip to anterior margin of eye) 7.6 (left) to 8.0 (right) mm; eye to tympanum length (from hind margin of eye to anterior border of tympanum)

8.9 mm; tympanum width 2.6 mm; tympanum height 3.7 mm; snout to forelimb length 36.8 mm; axilla to groin length 51.4 mm; minimum neck width 13.6 mm; midbody width 21.6 mm; midbody height 12.1 mm; forelimb length (from body insertion to base of claw of fourth finger) 29.0 mm; hindlimb length (from body insertion to base of claw of fourth toe) 38.7 mm; length of fourth toe (without claw) 13.4 mm.

This second preserved adult male known of *T. noggei* largely corresponds with the description of the male holotype provided by Ziegler *et al.* (2005), except for the following characters: 1) frontonasal being not only in contact with rostral, nasals, anterior loreals, and prefrontals, but also with the frontal (because the prefrontals are separated, and not in contact, as it is the case in the male holotype); 2) frontal in contact with frontonasal; 3) supraoculars laterally bordered by two (right) to three (left) supraciliaries (versus five supraciliaries each in the holotype); 4) left supraciliary row complete along the entire length of the lateral edge of the supraoculars, as it is also the case in the holotype, but right supraciliary row incomplete (ending at third supraocular); 5) each parietal is followed by two enlarged nuchals (three in the holotype); 6) 43 middorsal scales (instead of 44 in the holotype) from posterior end of parietals to posterior margin of thigh (paravertebral scales); 7) subdigital lamellae smooth, numbering 20 (versus 18-20 in the holotype) on the fourth digit of the pes; 8) seven pale brown transverse bands (opposite to eight to nine in the holotype) are discernible on the dorsum between the limbs and ten or more light bands (opposite to 17 in the holotype) on the dorsal tail.

Some important measurements, the number of dorsal body bands and selected scalation characters of four female specimens that were collected in Phong Nha - Ke Bang subsequent to the original description (Ziegler *et al.*, 2005) are listed in Tab. 1. Respective data of additional 14 specimens that were captured and subsequently released between 16 July and 27 August 2006 are summarized in Tab. 2. Due to this new data gathered from the afore mentioned 19 specimens in addition to the type series, the diagnosis of *T. noggei* given in Ziegler *et al.* (2005) must be partially modified as follows: 1) existence of six to nine (mean 7.5) transverse body bands between the limbs; 2) the supraoculars are bordered by two to five supraciliaries; 3) the number of midbody scale rows ranges from 22-24 (mean 22.4), with 5-6 (mean 5.9) dorsals, each 5-6 (mean 5.2) laterals, and 6-7 (mean 6.1) ventral scales; 4) 43-49 (mean 47.1) middorsal (paravertebral) scales (see also Tab. 3).

HEMIPENIS MORPHOLOGY

A description of the partly everted hemipenes of the holotype of *Tropidophorus noggei* was provided by Ziegler *et al.* (2005). Meanwhile, with the subsequently everted and ca. 15 mm long left hemipenis of the specimen MHNG 2683.99 (Fig. 2) we have a better prepared outer genital organ at hand. It corresponds very well with the description of the hemipenes of the holotype, viz. being elongate, unpigmented and having a smooth pedicel without any further ornamentation, too. The sperm groove of the left hemipenis of the specimen MHNG 2683.99 is bordered with lips, apically forked and each running as well along the apical lobes. Furthermore, the truncus laterally bears each a thin-skinned tissue bulge. Asulcally, the transitory area between the truncus and apex is at a turgid state marked by two inflated, thin-skinned rises;

TABLE 1. Selected measurements (in mm), number of dorsal body bands between limbs and some scalation characters of the four female *Tropidophorus noggei* deposited in the collection of the Science Research Centre of the Phong Nha - Ke Bang National Park, Quang Binh Province; for abbreviations see Material and Methods.

|  | PNNP 111 | PNNP 112 | PNNP 174 | PNNP 175 | Min - max (x ± s) |
|---|---|---|---|---|---|
| SVL | 101.4 | 104.2 | 101.2 | 110.2 | 101.2 - 110.2 (104.3 ± 4.2) |
| HL | 20.3 | 20.6 | 19.6 | 21.1 | 19.6 - 21.1 (20.4 ± 0.6) |
| HW | 16.1 | 16.0 | 15.7 | 16.9 | 15.7 - 16.9 (16.2 ± 0.5) |
| BB | 8 | 7 | 7 | 6 | 6 - 8 (7 ± 0.8) |
| MS | 22 | 22 | 24 | 23 | 22 - 24 (22.8 ± 1.0) |
| D | 5 | 5 | 6 | 5 | 5 - 6 (5.3 ± 0.5) |
| V | 6 | 6 | 6 | 6 | 6 |
| L | 5/6 | 5/6 | 6/6 | 6/6 | 5 - 6 (5.8 ± 0.5) |

along each of the outer margins of the two rises, few plicae (petala sensu Savage, 1997; terminology used herein after Ziegler & Böhme, 2004) are discernible. Although the apical lobes of the everted left hemipenis of the specimen MHNG 2683.99 are terminally not completely everted, they allow a better genital morphological analysis than it was the case with the only partially protruded hemipenes of the holotype of *T. noggei*. Asulcally, above the two inflated, thin-skinned rises the actual plica ornamentation stretches more or less horizontally along the sulcal, lateral and asulcal sides of the apex, below the apical lobes. These plicae, which are relatively difficult to discern and therefore hardly countable, are differentiated from the truncus by a distinct tissue seam. In addition, the "deeply bifurcated hemipenis" corroborates placement of the genital morphologically poorly known genus *Tropidophorus* in the *Sphenomorphus* group (Greer, 1979; Greer & Biswas, 2004).

NATURAL HISTORY

*Habitat and abundance*

Despite recent field research from June to August 2006 within different areas of the karst forests of Phong Nha - Ke Bang National Park, we only could record *T. noggei* in a single mountainous region of Cha Noi area (Figs. 3, 8), from where also the type series originated (Ziegler *et al.,* 2005). However, this is not astonishing, as the genus *Tropidophorus* exhibits considerable local endemism (e. g. Greer & Biswas, 2004). All specimens of *T. noggei* subsequently seen by us were found in the primary forest in altitudes between 300-400 m above sea level. Within seven field nights at such higher elevations we recognized 17 different specimens, of which 14 could be captured for marking and taking selected measurements as well as scalation characters and sub-

FIG. 2

Sulcal (a) and asulcal (b) view of the formerly invertedly fixed and subsequently everted left hemipenis of *Tropidophorus noggei* (MHNG 2683.99).

TABLE 2. Sex. selected measurements (in mm), transversal dorsal body bands between limbs, and selected scalation characters of the 14 captured and subsequently released specimens of *Tropidophorus noggei* from Phong Nha - Ke Bang (for abbreviations see material and methods); * - with regenerated tail tip.

| Nr. | Sex | SVL | TaL | HL | HW | BB | MD | MS | D | V | L |
|-----|-------|-------|--------|------|------|----|----|----|---|---|-----|
| 1 | ad. | 104.2 | 124.6 | 22.5 | 17.2 | 7 | | 22 | 6 | 6 | 5/5 |
| 2 | ad. | 90.0 | 106.0 | 20.2 | 14.1 | 6 | 48 | 22 | 6 | 6 | 5/5 |
| 3 | ad. | 68.8 | 93.0 | 16.2 | 12.1 | 8 | 47 | 22 | 6 | 6 | 5/5 |
| 4 | ad. | 94.1 | 91.0* | 22.5 | 17.8 | 7 | 43 | 22 | 6 | 6 | 5/5 |
| 5 | f pre | 96.2 | 101.5 | 21.2 | 17.0 | 7 | 49 | 22 | 6 | 6 | 5/5 |
| 6 | ad. | 106.5 | 123.5 | 21.0 | 16.3 | 8 | 48 | 23 | 6 | 7 | 5/5 |
| 7 | f pre | 93.6 | 97.0* | 20.0 | 15.3 | 8 | 48 | 22 | 6 | 6 | 5/5 |
| 8 | juv. | 71.5 | 89.2 | 16.3 | 12.0 | 7 | 48 | 22 | 6 | 6 | 5/5 |
| 9 | juv. | 84.9 | 113.8 | 19.9 | 14.2 | 8 | 48 | 22 | 6 | 6 | 5/5 |
| 10 | ad. | 94.2 | 109.2 | 22.2 | 17.1 | 8 | 47 | 23 | 6 | 6 | 6/5 |
| 11 | f pre | 103.3 | 97.4 | 22.1 | 16.2 | 6 | 49 | 22 | 6 | 6 | 5/5 |
| 12 | f pre | 102.1 | 93.8 | 21.3 | 17.1 | 7 | 48 | 23 | 6 | 6 | 5/6 |
| 13 | ad. | 84.4 | 111.3 | 21.2 | 17.0 | 7 | | | 6 | 6 | |
| 14 | juv. | 84.6 | 119.2 | 19.8 | 15.3 | 7 | 45 | 24 | 6 | 6 | 6/6 |

FIG. 3
Map showing the single known locality of *Tropidophorus noggei*.

sequently were released at the capture site. Eleven different specimens of *T. noggei* were recorded at a transect of 0.5 km within a single night only, from 19:14h to 23:37h, pointing to a regionally high abundance. Because eight of the 14 marked individuals have been captured at prominent karst formations, we were able to subsequently relocate the individual sites. After a period of five weeks we found six of the eight skinks at the same location anyway. This recapture rate of 75% explicitly argues for a seldom relocation, thus the territorial habits of *T. noggei*.

All our records of *Tropidophorus noggei* took place in heights of 0.3 to 1.5 m above the ground. With a piece of shed skin found on 21 June 2006 in a chink of a karst rock projection together with an observation of a specimen dwelling inside a karst crevice we also could prove that the species is at least able to climb up to 1.8 m height above the ground. The vertical diameter of the karst rock crevices in which we found live specimens, measured seven to 50 mm (mean ca. 20 mm). With the dorso-ventrally depressed body as well as the robust and resistant scalation the species is exceedingly adapted to such narrow rock crevices (Figs. 4-5). All specimens recognized by us were found solitarily, however, nine (i. e. ca. 64%) of the 14 captured specimens lingered in crevices of immediate vicinity, within distances of 0.3 to 1 m to each other. This suggests, that *T. noggei* occupies certain territories and that adults as well as juveniles together with adults occur in close vicinity.
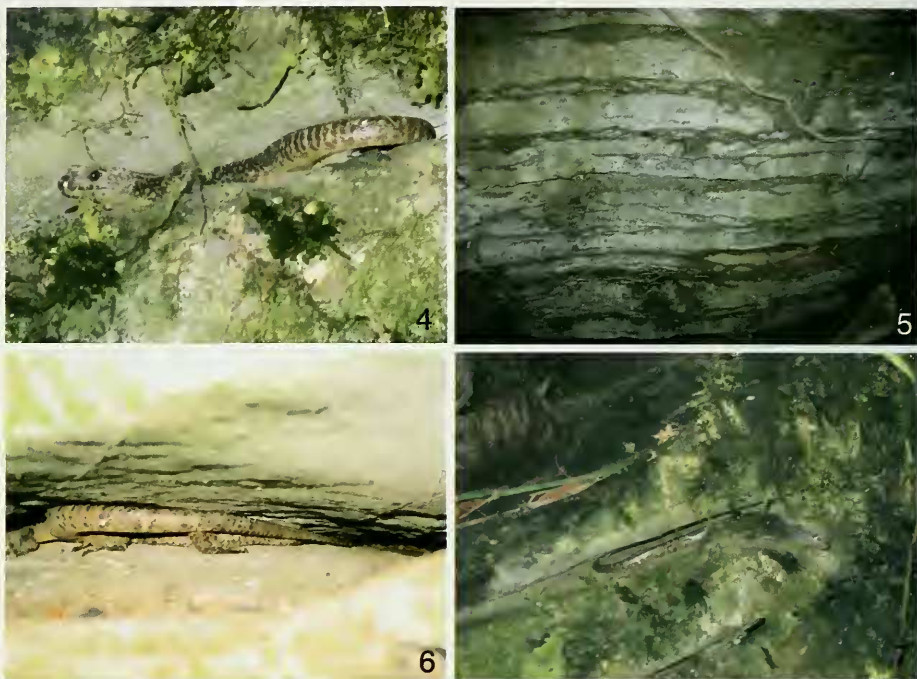
FIGS 4-7

(4) *Tropidophorus noggei* active during daytime in front of its hiding place, a narrow karst rock crevice. (5) Such narrow karst rock crevices represent the microhabitat of *Tropidophorus noggei*. (6) *Tropidophorus noggei* at night in its hiding place in typical sleeping as well as defending position. (7) *Tropidophorus noggei* during daytime lurking at the entrace of a karst crevice.

Further lizard species that were observed by us in syntopy with *T. noggei* were scincids of the genera *Lygosoma* and *Scincella*, the gekkonids *Cyrtodactylus phongnhakebangensis*, *C. cryptus*, *Gekko gecko*, *G. scientiadventura*, as well as the agamids *Acanthosaura lepidogaster* and *Calotes emma* (Heidrich *et al.*, 2007; Ziegler *et al.*, 2007). As potential predators of at least juvenile *T. noggei* we found large centipedes (*Scolopendra* sp., *Scutigera* sp.) crawling in and around the karst rock crevices. Furthermore, the snake species *Psammodynastes pulverulentus* and *Protobothrops cornutus*, as well as *Lycodon* representatives were observed occuring together with *T. noggei*.

*Activity and habits*

Ziegler *et al.* (2005) reported, that *T. noggei* specimens were found at night at the base of karst rock outcrops in front of horizontal and narrow rock crevices about 30 to 50 cm above the forest floor. After being disturbed, they escaped into the narrow rock crevices, where they were well concealed and anchored up to 15 to 30 cm inside the karst rock crevices. During our recent ecological field work we could find out that most skinks spent the night resting or sleeping in narrow rock crevices. We further

Fig. 8

Habitat of *Tropidophorus noggei* in Cha Noi area, Phong Nha - Ke Bang National Park, Quang Binh Province, Truong Son, central Vietnam.

observed a typical defensive position (Fig. 6), with the tail, being laterally positioned in front of the body to protect the damageable trunk parts and the head. It seems that the species is also able to autotomize its tail once being heavily grasped at, which was once observed by us on 21 June 2006. Further, *T. noggei* was observed by us to be mainly active during daytime. However, also at daytime, the crevices were seldomly left. For example, the adult specimen 1 (see Tab. 2 and 4), that was observed at the afternoon of 7 August 2006 for a period of two hours (15:15 to 17:15), left its crevice only once for a short time and remained only in a range of about one meter in doing so. The skink rather spent most of the two hours of our observation lurking at its crevice entrance (Fig. 7).

*Reproduction*

Concerning reproductive biology, the testes of the male MHNG 2683.99 measured 5.8-6.3 mm in length and 3.2-3.6 mm in width. The testes of the commen-surate male holotype measured 9.0 mm in length and 6.2 mm in width (Ziegler *et al.,* 2005). Whilst the specimen MHNG 2683.99 most probably was collected during the dry season, the larger testes of the holotype may be established by its collect at the end of the dry season. One of the two female paratypes, that was also collected at the end

TABLE 3. Maximum snout-vent length, head length, and head width of the three type specimens of *Tropidophorus noggei* (from Ziegler *et al.,* 2005), of the subsequently collected male MHNG 2683.99, of the four specimens deposited in the Science Research Centre of the Phong Nha - Ke Bang National Park (see Table 1), and of the 14 captured and subsequently released specimens (see Table 2), as well as minima, maxima, mean and standard deviation of the number of dorsal body bands between the limbs and of selected scalation characters (for abbreviations see material and methods).

|          | n  | Min-max<br>x ± s |
|----------|----|------------------|
| SVL max. | 22 | 110.2 mm         |
| HL max.  | 22 | 22.5 mm          |
| HW max.  | 22 | 17.8 mm          |
| BB       | 22 | 6-9<br>(7.5 ± 0.9) |
| MD       | 16 | 43-49<br>(47.1 ± 2.1) |
| MS       | 21 | 22-24<br>(22.4 ± 0.7) |
| D        | 22 | 5-6<br>(5.9 ± 0.4) |
| V        | 22 | 6-7<br>(6.1 ± 0.2) |
| L        | 21 | 5-6<br>(5.2 ± 0.4) |

TABLE 4. Collecting date, sex, weight (in g), time of discovery, temperature, relative humidity and vertical karst crevice diameter (CD: in mm) as well as crevice height above ground (CH: in m) for the 14 captured and subsequently released specimens of *Tropidophorus noggei* from Phong Nha - Ke Bang. For abbreviations see Material and Methods; further abbreviations are as follows: Ad. - adult; f - female; pre - pregnant; juv. - subadult.

| Nr. | Date  | Sex   | Weight | Time  | Temp.   | Humidity | CD      | CH  |
|-----|-------|-------|--------|-------|---------|----------|---------|-----|
| 1   | 16.7. | ad.   | 25     | 18:56 | 24.9°C  | 94%      | 18      | 1.0 |
| 2   | 17.7. | ad.   | 19     | 19:14 | 24.3°C  | 94%      | 13-27   | 1.0 |
| 3   | 17.7. | ad.   | 6.5    | 19:25 | 24.3°C  | 94%      | 7-19    | 0.3 |
| 4   | 17.7. | ad.   | 23     | 19:49 | 24.1°C  | 93%      | 22-34   | 1.5 |
| 5   | 17.7. | f pre | 24.5   | 19:55 | 24.1°C  | 93%      | 33-50   | 1.5 |
| 6   | 17.7. | ad.   | 30.5   | 20:37 | 24.3°C  | 93%      | 9-23    | 0.4 |
| 7   | 17.7. | f pre | 22     | 21:14 | 24.4°C  | 92%      | 14-22   | 1.2 |
| 8   | 17.7. | juv.  | 6.5    | 21:25 | 24.4°C  | 93%      | 18      | 1.2 |
| 9   | 17.7. | juv.  | 14     | 21:45 | 24.4°C  | 92%      | 11      | 1.3 |
| 10  | 17.7. | ad.   | 19.5   | 22:16 | 24.4°C  | 92%      | 11-30   | 1.4 |
| 11  | 17.7. | f pre | 24     | 22:27 | 24.2°C  | 88%      | 14.5-16 | 0.8 |
| 12  | 17.7. | f pre | 30     | 23:37 | 24.2°C  | 88%      | 17-20   | 0.7 |
| 13  | 27.8. | ad.   | 21     | 21:10 | 25.0°C  | 86%      |         | 1.0 |
| 14  | 27.8. | juv.  |        | 21:20 | 25.0°C  | 86%      | 14-18   | 1.1 |

of the dry season, contained three large eggs of about 13 x 10 mm diameter. The four female specimens deposited in the collection of the Science Research Centre of the Phong Nha - Ke Bang National Park most probably were collected during different seasons. The two specimens (PNNP 111, PNNP 112), that most probably were collected during the dry season, contained nine and 18 small eggs of 2-3 and 1-4 mm maximum diameter, respectively. In contrast, the specimen PNNP 174 contained five eggs of 12.5 x 8 mm maximum diameter, and in the dissected specimen PNNP 175 we found seven eggs of 10.6 x 8.9 mm size. Throughout July, at the end of the dry season, we found pregnant females in the field (see Tab. 4), well recognizable from their distinctly swollen bodies. It should be interesting to continue with studying the species' reproductive mode (see Hikida *et al.*, 2002), because several authors have assumed that in lizards the physical constraint from the crevice-dwelling habits provides an evolutionary force to some reproductive traits, such as relative clutch mass and frequency of clutch production (Vitt, 1981, 1993; Doughty & Shine, 1995).

*Diet*

With respect to feeding ecology, we found remains of a worm-like invertebrate (cf. Annelida) in the stomach of MHNG 2683.99. The stomachs of the four females deposited in the collection of the Science Research Centre of the Phong Nha - Ke Bang National Park contained each remains of a worm (Annelida) in the specimens PNNP 174 and PNNP 175, and three ants (Hymenoptera: Formicidae) in the specimen PNNP 111. The stomach of the female PNNP 112 was empty, but its gut contained four ants, four termites (Isoptera) and one katydid (Ensifera). Whereas the guts of the specimens PNNP 174 and PNNP 175 were empty, the gut of PNNP 111 contained five ants. The contents of the gastro-intestinal tracs of the afore mentioned specimens together with the data obtained from the dissected holotype and one female paratype of *T. noggei* (see Ziegler *et al.*, 2005) are summarized in Fig. 9.

The most frequent prey items were ants and termites, followed by annelid worms (see Fig. 9). However, the higher prey item amount in the guts as can be seen in Fig. 9 is put down to an accumulation of prey fragments that are hard to digest to not digestible, as is the case with chitin fragments of ants and termites. For this reason, and because gut contents usually do not contain easily digestible prey like soft-skinned insect larvae or worms, and therefore have limited value in comparison with more diverse stomach contents, stomach and gut content data were presented separately in Fig. 9 (see also Ziegler, 2003). Therefore the high number of ant and termite prey items must be carefully interpreted. In addition, only prey item numbers are presented in   Fig. 9 and not their respective masses. To visualize this in a direct comparison: three of the relatively large annelid worms (with at least 3 mm body diameter) were found in the stomachs of three (43%) of the altogether seven dissected skinks, but the much more smaller ants were only in the guts of two individuals (29%) and the 5 mm small termites only in the gut of a single skink (14%). Based on the worms' high biomasses and the fact that 43 percent of the skinks had worm remains in their stomach, it can be assumed that worms play an important role in the feeding ecology of *T. noggei*. In addition, it is interesting to note, that ants only were found in the gastro-intestinal tracts of the specimens      PNNP 111 and PNNP 112, the latter one of which contained as
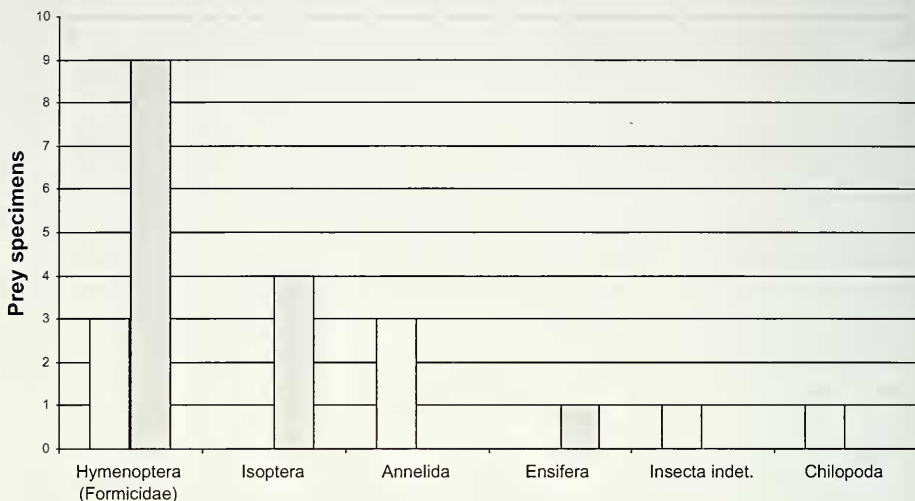
F̄ɪɢ. 9

Number of prey items found in the stomachs (white columns) and guts (grey columns) of seven examined specimens of *Tropidophorus noggei*.

single skink specimen also termites. Due to their small egg sizes, both skinks most probably were collected during another season than the females PNNP 174 and PNNP 175, which both had worm remains in their stomachs, as well as the male MHNG 2683.99, that most probably was collected during or at the end of the dry season. This further would allow the conclusion of a seasonal food supply and prey spectrum, respectively, because it can be expected that the worm abundance increases with beginning rains. However, during our field work in July and August 2006 we found both earth worms, as well as ants and termites in and around the karst crevices being inhabited by *T. noggei*.

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